REMARKS/ARGUMENTS

Favorable reconsideration of the present application is respectfully requested.

Applicant acknowledges the continuation of the election of species requirement. The Official Action indicates that Claims 1-3, 6 and 7 have been withdrawn from further consideration. Claim 7 has been canceled herein, and the remaining claims are presented in the Listing of Claims as being in "withdrawn" status. The subject matter of Claim 7 has, however, been presented in new Claim 10, which depends from new Claim 8, with Claim 8 loosely corresponding to prior Claim 4. The subject matter of Claim 10 is readable on Species IX (bottomed hole of spider shaft shown in FIG. 10A), and thus the claim should not be treated as being directed to a non-elected species.

An objection was made to the drawings, on the basis that the reference numerals 3, 5, 6, 7, 10 and 12 have been used to identify parts in more than one embodiment of the invention, which parts are modified in the different inventions. Applicant has submitted herewith replacement sheets of drawings which make the necessary changes in the reference numerals such that the modified parts are identified by different reference numerals. The specification has also been revised to change the reference numerals used therein to correspond to the changes in the drawings.

The objection to the specification related to the expression, "the noises occurs", appearing at page 19, line 24, is believed to have been overcome by the change made at that location in the Substitute Specification. Other revisions to the specification have been made in the Substitute Specification to correct minor errors and the like. No new matter has been included in the Substitute Specification. Withdrawal of the objection to the specification is respectfully requested.

Claims 4 and 5 were initially rejected under 35 USC §112, second paragraph, as being indefinite. Specific objection was made, in Claim 4, to the recitation that a spider shaft was to be fitted in "a possible oscillating manner" into a bearing hole. The Official Action noted that the use of the term "possible" connoted that the oscillating condition may or may not exist, thus rendering the claim indefinite. Claim 4 has been canceled in favor of new Claim 8, which does not employ this or any similar language. The rejection of Claim 4 under 35 USC §112, second paragraph, should thus be withdrawn.

Claim 5 was objected to on the basis that the term "extreme" is a relative term which renders the claim indefinite. Applicant notes that several examples of what would be regarded by Applicant and those of ordinary skill in the art to be extreme-pressure additives are identified at page 17, lines 1-8 of the original specification. Those skilled in the art would thus clearly understand that these listed additive candidates, and any others possessing similar properties or characteristics, would be included within the meaning of the term "extreme-pressure additive". The Takabe published US application, cited in the Official Action, uses the term as well, which is further evidence that the term has an understood meaning in the art. Applicant thus believes that persons of ordinary skill in the art would readily understand what is meant by the term in Claim 5, and now in new Claim 9, which effectively replaces canceled Claim 5. Withdrawal of the rejection under 35 USC §112, second paragraph, is therefore respectfully requested.

Claim 4 was initially rejected under 35 USC §102(b) as being anticipated by the Kayser patent (US 3,138,942). Claim 5 was rejected under 35 USC §103(a) as being obvious in view of a combination of the teachings of Kayser and US Published Patent Application US2001/0007832, to Takabe. Claims 4 and 5 have been canceled

herein, as has Claim 7, which also depended from Claim 4, and new Claims 8-10 are presented as replacements therefor. These new claims all read on the elected species of FIGS. 10a and 10b, and are also believed to be allowable over the cited references.

In the Official Action, it is asserted that the Kayser patent discloses yokes formed with bearing holes, and a spider shaft fitted into the bearing hole through a needle bearing. It is further asserted that the Kayser patent discloses that the needle bearing can be fitted to a spider shaft in any suitable manner (Col. 2, lines 65-68), and further that the use of an interference fit would be appropriate (Col. 3, lines 33-36). These disclosures do not, however, give rise to an anticipation of prior Claim 4 or new independent Claim 8.

Claim 8 calls for the rollers provided in the needle bearing to be interference-fitted on an end periphery of the end portion of the spider shaft extending through the rollers. This construction reduces or eliminates an undesirable feeling experienced by a driver, brought about by the presence of some amount of clearance or play in a cross-joint used in a steering apparatus. The Kayser patent does not disclose or suggest the claimed construction.

The passages referred to in the Official Action as allegedly anticipating this claim limitation are not directed to the connection or coupling of the spider shaft to the rollers of the needle bearing, and thus those passages are not relevant to the claim limitation at issue. The cited passage at Column 2 of Kayser relates to the securement of the cup-shaped bearing race to the furcation of a universal joint member, which is not shown in the drawing figures in Kayser. This relates to connecting the exterior of the cup-shaped bearing race to another component. Whatever the "suitable manner" of securement might be in this instance, it clearly has no bearing on the coupling of a

spider shaft to the rollers of a needle bearing, which would occur, if at all, in the interior of the cup-shaped bearing race.

The disclosure of the possible use of an interference fit in Column 3 of Kayser also does not relate to the coupling or connection of a spider shaft to the rollers of a needle bearing. Instead, this passage relates to the securing of the seal-engaging diameter of the trunnion to a metallic portion 38 of a sealing means36, which is provided to isolate the interior of the cup-shaped bearing race, and the components located therein, from the external environment. It is discussed that an interference fit of the trunnion to the bearing race will insure proper sealing and to ensure that the metallic portion of the seal can be pressed securely against a shoulder formed on the trunnion.

Again, these passages do nothing to disclose or suggest that the peripheral end portion of a spider shaft could be or should be interference-fitted to the rollers of a needle bearing in the claimed construction. Accordingly, the Kayser patent cannot be said to identically disclose or render obvious the invention as set forth in Claim 8.

The Kayser patent discloses that the needle bearings 24 therein are free to move radially (Col. 3, lines 64-65), thus further evidencing that the construction in that patent does not anticipate current Claim 8. Withdrawal of the rejection under 35 USC §102(b) is warranted, and is respectfully requested.

New Claims 9 and 10 are also not anticipated or rendered obvious by the Kayser patent, either alone or in combination with the cited Takabe published patent application. These claims depend from Claim 8, which is believed to be allowable for at least the reasons set forth above. The Takabe patent does not appear to contain any disclosure that would overcome the deficiencies of the Kayser patent with regard to the patentability of Claim 8. Accordingly, Applicant respectfully submits that the

rejections under 35 USC §102(b) and 35 USC §103(a) in the Official Action are not applicable to Claims 9 and 10, and the rejections should be withdrawn.

Applicant believes that all claims as now presented are in condition for allowance, and that all objections and rejections have been addressed and overcome. Passage of the application to issue at an early date is earnestly solicited.

Authorization is hereby given to charge any fee that is deemed to be owed as a result of the filing of this Amendment, to Deposit Account No. 501165. A duplicate copy of this paper is enclosed for deposit account charging purposes.

Respectfully,

MILES & STOCKBRIDGE P.C.

By: Mitchell W. Shapiro
Reg. No. 31,568

John C. Kerins
Reg. No. 32,421

1751 Pinnacle Drive, Suite 500
McLean, Virginia 22102-3833
Telephone: (703) 610-8649
#9198921 v1

MARKED-UP COPY OF ORIGINAL SPECIFICATION

SEP 02 2003 C I P E

NSK2356US

CROSS JOINT

This application claims the benefit of Japanese Patent Applications No. 2000-371934, 2001-219935, 2001-313941 and 2001-313945 which are hereby incorporated by reference.

RECEIVED
SEP 0 5 2003
GROUP 3600

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a cross joint used for a steering apparatus for, e.g., a vehicle.

Related Background Art

In the steering apparatus for the vehicle, a cross joint constructed of a pair of yokes and a cross-shaped spider and serving to propagate a torque in a way that rotates a predetermined bending angle, is interposed between, for instance, an upper shaft and a lower shaft of a steering shaft.

According to a cross joint disclosed in, e.g., Japanese Patent Application Laid-Open No.2000-170786, a shaft member of the spider is fitted ~~in a possible of oscillating manner~~ into a bearing hole of a yoke through a needle bearing such that said shaft member is capable of oscillating. A spherical protrusion formed on an axial core of an inner surface of a cup of the needle bearing is fitted into and kept in contact by pressure with a conical hole formed in the axial

core of the spider shaft.

With this configuration, even when ~~the~~ vibrations are propagated from wheels, a minute gap between the spider shaft and the needle bearing is kept uniform, thereby preventing an emission of noises due to an interference between the spider shaft and the needle bearing.

According to the structure disclosed in Patent Application Laid-Open No.2000-170786, however, if a dimensional accuracy of each component is low, when the cross joint is ~~assembling~~ assembled to the yokes, it is difficult to bring the spherical protrusion provided on the inner surface of the cup of the needle bearing into contact with the conical hole of the spider shaft ~~by~~ with a proper pre-load. As a result, a minute gap between the spider shaft and the needle bearing can not be kept uniform, resulting in an emission of noises due to an interference therebetween.

~~By contrast,~~ On the other hand, if the dimensional accuracy of each component is enhanced, though capable of preventing the emission of noises, a rise in manufacturing cost is brought about as a negative aspect.

Further, when a steering shaft of the vehicle is steered, a steering wheel is rotated, with the result that the spider shaft is oscillated. An angle of this oscillation is determined by a joint fitting

angle in the vehicle and is on the order of ±30 degrees in the case of an ordinary car. The rollers of the needle bearing smoothly rotate owing to the oscillations of the spider shaft.

According to Japanese Patent Application Laid-Open No.2000-170786, however, the axial core of the roller is not parallel but inclined to the axis of the spider shaft in many cases, and the roller, with its rotation, moves in the axial direction within the cup of the needle bearing. With the movement of the roller in the axial direction, the roller comes into contact with the cup wall, and sliding contact occurs between the roller and the cup wall. As a result, a bending torque of the steering shaft increases, and a smooth feeling of steering can not be obtained.

SUMMARY OF THE INVENTION

It is a first object of the present invention, which was devised under such circumstances, to provide a cross joint capable of ~~surely~~ reliably preventing an emission of noises due to an interference between a spider shaft and a rolling bearing without causing any rise in manufacturing cost.

It is a second object of the present invention to provide a cross joint capable of ~~surely~~ reliably preventing the emission of noises due to the interference between the spider shaft and the rolling bearing and

obtaining a smooth feeling by educing a bending torque of a steering shaft without bringing about any rise in manufacturing cost.

To accomplish the above objects, according to one aspect of the present invention, a cross joint comprises yokes each formed with a bearing hole, and a spider shaft rotatably fitted into the bearing hole through a rolling bearing. The spider shaft is formed with a contact portion with the rolling bearing, the contact portion having its outside diameter larger than an outside diameter of the spider shaft.

In the cross joint according to the present invention, preferably, an axial core side end surface of the contact portion is formed with a bottomed hole. Thus, according to the present invention, the contact portion of the spider shaft is set larger than that of the central portion thereof, and hence the fitting between this contact portion and the rolling bearing can be set to have an interference (or a minute gap). Accordingly, even when vibrations are propagated from the wheels, the noises emitted due to the interference between the spider shaft and the rolling bearing can be ~~surely~~ reliably prevented by keeping uniform the minute gap between the central portion of the spider shaft and the rolling bearing.

On the other hand, the contact portion of the

spider shaft has the bottomed hole at a central portion of the spider shaft end and is, in this case, formed in a comparatively thin ring shape. Hence, the contact portion has a comparatively small rigidity in its radial direction and, even when the fitting between the contact portion and the rolling bearing is set to have the interference, causes neither a large contact surface pressure nor a problem in terms of durability. Further, similarly, when assembling the cross joint to the yoke, a load for inserting (press-fitting) the rolling bearing (needle bearing) is relatively small, and there is ~~caused~~ no ~~trouble to~~ real difficulty with the assembly process. Moreover, there is no necessity of enhancing a dimensional accuracy or improving of each component, ~~and~~ the contact portion of the spider shaft is expanded in its diameter and is formed merely with the bottomed hole. This configuration does not bring about a rise in the manufacturing cost.

Moreover, the contact portion of the spider shaft is formed in ~~the~~ a comparatively thin ring shape. Therefore, if a large load is propagated, the contact portion becomes flexural, however, the central portion of the spider shaft receives a large proportion of the load. Hence, there does not arise ~~the~~ any significant problem in terms of ~~the~~ strength.

Further, in the cross joint according to the

present invention, an extreme-pressure additive may be added to a lubricating agent filling an interior of the needle bearing.

According to another aspect of the present invention, a cross joint comprises yokes each formed with a bearing hole, and a spider shaft fitted ~~in a possible oscillating manner~~ into ~~the~~ a bearing hole through a needle bearing in a manner such that the shaft is capable of oscillating movement. The needle bearing is interference-fitted to the spider shaft, and rollers and provided in a bearing cup of the needle bearing are so structured as to be movable 0.6 mm or larger in the axial direction.

Thus, according to the present invention, the needle bearing and the spider shaft are interference-fitted to each other, and it is therefore feasible to ~~surely~~ reliably prevent the emission of noises due to the interference between the spider shaft and the needle bearing without bringing about any rise in manufacturing cost.

~~Besides~~, In addition, the rollers in the bearing cup of the needle bearing are so structured as to be movable 0.6 mm or larger in the axial direction. Hence, even if the rollers rotate and move in the axial direction within the cup when the spider shaft is oscillated, the rollers do not come into contact with the cup wall, and ~~there is caused no~~ no sliding contact between the rollers and the cup wall is experienced. Accordingly, it is

possible to obtain the smooth feeling of steering by reducing the bending torque of the steering shaft.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side view including a partially cut-off section, showing a cross joint in a first embodiment of the present invention;

FIG. 2 is a sectional view of the cross joint shown in FIG. 1;

FIG. 3 is a sectional view of a cross joint shown in a second embodiment of the present invention;

FIG. 4 is a sectional view of a cross joint shown in a third embodiment of the present invention;

FIG. 5 is a sectional view of a cross joint shown in a fourth embodiment of the present invention;

FIG. 6 is a sectional view of a cross joint shown in a fifth embodiment of the present invention;

FIG. 7 is a sectional view of a cross joint shown in a sixth embodiment of the present invention;

FIG. 8 is a sectional view (taken in the direction of a vertical axis of the center of the joint in FIG. 1) of a cross joint shown in a seventh embodiment of the present invention;

FIG. 9 is a sectional view of a cross joint shown in an eighth embodiment of the present

invention;

FIG. 10A is a side view including a partially cut-off section, showing a cross joint shown in a ninth embodiment of the present invention;

FIG. 10B is a sectional view of the cross joint shown in FIG. 10A;

FIG. 11 is a sectional view of a cross joint shown in a tenth embodiment of the present invention;

FIG. 12 is a sectional view of a cross joint shown in an eleventh embodiment of the present invention;

FIGS. 13A and 13B are sectional views each showing a cross joint shown in a twelfth embodiment of the present invention;

FIG. 14A is a sectional view of a cross joint in a thirteenth embodiment of the present invention; and

FIG. 14B is a sectional view of a cross joint in a fourteenth embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[First Embodiment]

FIG. 1 is a side view including a partially cut-off section, showing a cross joint in a first embodiment of the present invention. FIG. 2 is a sectional view of the cross joint illustrated in FIG. 1.

As shown in FIG. 1, the cross joint has a cross-shaped spider 3 ~~is~~ interposed between a pair of yokes 1 and 2. To be more specific, as shown in FIG. 2, a spider shaft 6 is rotatably fitted into a bearing hole 4 of the yoke 1 through a needle bearing 5. A seal member 7 is provided along an outer periphery of a lower portion of the spider shaft 6. ~~Note that the~~ The yoke may be manufactured by any one of sheet metal working, forging and casting and composed of any one of ferro-series and alumi-series materials.

Further, a pin 9 composed of a synthetic resin is inserted into an axial hole 8 formed in an axial core of the spider shaft 6. The needle bearing 5 is provided with a metallic cup 10 fitted in the bearing hole 4. A plurality of rolling members (rollers) 11 are arranged inwardly of this cup 10.

In the first embodiment, an outside diameter of a contact portion 6a of the spider shaft 6 is set larger than an outside diameter of a central portion 6b thereof, and a bottomed hole 12 is formed at a central portion of each end of the spider shaft 6.

Thus, the outside diameter of the contact portion 6a of the spider shaft 6 is set larger than that of the central portion 6b thereof, and hence the fitting between this contact portion 6a and the needle bearing 5 can be set to have an interference (or a minute gap). Accordingly, even when vibrations

are propagated from the wheels, noises emitted due to the interference between the spider shaft 6 and the needle bearing 5 can be ~~surely~~ reliably prevented by keeping uniform the minute gap between the central portion 6b of the spider shaft 6 and the needle bearing 5.

On the other hand, since the contact portion 6a of the spider shaft 6 has the bottomed hole 12 at the central portion of the end of the spider shaft 6, the contact portion 6a is formed in a comparatively thin ring shape. Hence, the contact portion 6a has a comparatively small rigidity in its radial direction and, even when the fitting between the contact portion 6a and the needle bearing 5 is set to have the interference, causes neither a large contact surface pressure nor a problem in terms of durability. Further, similarly, when assembling the cross joint to the yoke 1, a load for inserting (press-fitting) the needle bearing 5 is relatively small, and there is ~~caused~~ no real difficulty with ~~trouble to~~ the assembly process.

Moreover, there is no necessity of enhancing a dimensional accuracy of each component, and the contact portion of the spider shaft 6 is expanded in its diameter and is formed merely with the bottomed hole 12. This configuration does not bring about a rise in the manufacturing cost.

Moreover, the contact portion 6a of the spider shaft 6 is formed in ~~the~~ a comparatively thin ring

shape. Therefore, if a large load is propagated, the contact portion 6a becomes flexural, however, the central portion 6b of the spider shaft 6 receives a large proportion of the load. Hence, there does not arise ~~the~~ any significant problem in terms of ~~the~~ strength.

~~Note that an~~ An axial diameter of the spider shaft is approximately 10 mm, a depth of the bottomed hole 12 is 1.8 through 3.5 mm and preferably 2 through 3 mm, a radial thickness of the thin ring-shaped portion of the contact portion 6a is 0.6 to 1.2 mm, and a level difference (that is, a minute gap S in FIG. 2 between the central portion 6b and the rolling member 11) is 0.004 to 0.020 mm. Note that the minute gap indicated by the symbol S is illustrated in exaggeration.

Further, a material of ~~a~~ spider 3 is JIS chrome molybdenum steel material SCM420 or 421, or chrome steel material SCr420 or 430. Moreover, a thermal treatment of the spider 3 is an overall carburization quenching treatment, and preferably the bottomed hole 12 is prevented from being carburized. Further, the outside diametric portion of the spider shaft 6 is worked by grinding, and a chamfer portion of the side end surface is not ground. Moreover, the cross joint in the first embodiment is used mainly in an engine room for a vehicle.

[Second Embodiment]

FIG. 3 is a sectional view showing a cross joint in a second embodiment of the present invention. according to the second embodiment, the synthetic resin pin 9 is not provided, and therefore the bottomed hole ~~12~~ 112 takes a conical shape, which leads to a less cost than in the first embodiment.

The cross joint in the second embodiment is, however, limited to the use in the driving room. Further, the seal member ~~7~~ 107 is composed of a nitrile rubber. Other configurations and operations are the same as those in the first embodiment.

[Third Embodiment]

FIG. 4 is a sectional view showing a cross joint in a third embodiment of the present invention. According to the third embodiment, the contact portion of the spider shaft is formed as a separate member. Namely, the spider shaft ~~6~~ 206 is formed with an axial hole 13, and a separate spacer 14 is fitted into this axial hole 13.

A protrusion 14a of this spacer 14 is press-fitted into the axial hole 13, and a thin ring-shaped portion 14b of the spacer 14 functions as the contact portion 6a in the first and second embodiments does. According to the third embodiment, the grinding of the outside diametric portion of the spider is easier than in the first and second embodiments. Other configurations and operations are the same as those

in the first embodiment.

[Fourth Embodiment]

FIG. 5 is a sectional view showing a cross joint in a fourth embodiment of the present invention. The fourth embodiment has such a configuration that ~~the~~ a bottomed hole ~~12~~ is not provided in contrast with the first embodiment.

Therefore, the working of the spider shaft ~~6~~ 306, 306a, 306b becomes easier than in the first embodiment. The contact surface pressure with the needle bearing 5 is, however, higher than in the first embodiment, and hence there is a necessity of setting the interference with the needle bearing 5 smaller than in the first embodiment. Other configurations and operations are the same as those in the first embodiment.

[Fifth Embodiment]

FIG. 6 is a sectional view showing a cross joint in a fifth embodiment of the present invention. A configuration in the fifth embodiment is that, in contrast with the first embodiment, the spider shaft ~~6~~ 406, 406a, 406b is not formed with ~~the~~ an axial hole ~~8~~ and is therefore solid, and a bottom central portion 15 of the cup ~~10~~ 410 of the needle bearing ~~5~~ 405 is brought into contact with a side end surface of the spider shaft ~~6~~ 406.

Hence, the working of the spider shaft ~~6~~ 406 is easier than in the first embodiment. The contact

surface pressure with the needle bearing ~~5~~ 405 is, however, higher than in the first embodiment, and hence there is a necessity of setting the interference with the needle bearing ~~5~~ 405 smaller than in the first embodiment. Other configurations and operations are the same as those in the first embodiment.

[Sixth Embodiment]

FIG. 7 is a sectional view showing a cross joint in a sixth embodiment of the present invention. a configuration in the sixth embodiment is that an interference portion of the fitting between the needle bearing 5 and the contact portion ~~6a~~ 506a of the spider shaft ~~6~~ 506 is set close to a proximal end of the spider shaft ~~6~~ 506.

Hence, the working of the spider shaft ~~6~~ 506 is easier than in the first embodiment. Other configurations and operations are the same as those in the first embodiment.

~~Note that the~~ The contact portion ~~6a~~ 506a of the spider shaft ~~6~~ 506 may be provided in an arbitrary position ranging extending from the front side end of the spider shaft ~~6~~ 506 to its proximal end.

[Seventh Embodiment]

FIG. 8 is a sectional view (taken in a direction of the vertical axis of the center of the joint in FIG. 1) showing a cross joint in a seventh

embodiment of the present invention. According to the seventh embodiment, one (an upper side in FIG. 8) of two pieces of spider shafts ~~6~~ 606 facing to each other is interference-fitted, while the other (a lower side in FIG. 8) is loose-fitted.

One interference-fitted spider shaft ~~6~~ 606 (the upper side in FIG. 8) has the contact (a large-diameter portion) ~~6a~~ 606a provided close to the proximal end thereof, and the distal end portion there is loose-fitted.

The other loose-fitted spider shaft ~~6~~ 606 (the lower side in FIG. 8) has no stepped portion and is formed in a straight shape.

A spider shaft ~~6~~ 606 orthogonal to the above spider shaft ~~6~~ 606 has the same configuration. Other configurations and operations are the same as those in the first embodiment.

Note that the cost required in the seventh embodiment might be less than in the first through sixth embodiments, however, the noise preventive effect gets declined. Further, if four pieces of spider shafts ~~6~~ 606 having the interference-fitted contact portions (large-diameter portions) ~~6a~~ 606a are reduced down to one single spider shaft ~~6~~ 606, a still less cost can be expected, however, the noise preventive effect falls into a further decline.

[Eighth Embodiment]

FIG. 9 is a sectional view showing across joint in an eighth embodiment of the present invention. A configuration in the eighth embodiment is that the interference-fitted contact portion (large-diameter portion) ~~6a~~ 706a is provided at the proximal end of the spider shaft ~~6~~ 706, a piece 16 is provided between the bottom surface of the cup ~~10~~ 710 and the side end surface of the spider shaft ~~6~~ 706. Other configurations and operations are the same as those in the first embodiment.

Note that a length (L) of the interference-fitted portion is set equal to or larger than 1.5 mm, preferably 2 mm on the basis of calculations and results of a multiplicity of tests performed. With this dimensional requirement attained, the durability can be ensured. Further, these numerical values are the same with the fourth through seventh embodiments.

Moreover, an outside diameter of the rolling member 11 is 1.4 to 2.3 mm, and the number of the rolling members 11 is 16 to 25. An outside diameter of the cup 10 is 15 to 16 mm. These numerical values are the same with the first through eighth embodiments.

Further, an extreme-pressure additive is added to grease (lubricating oil) filling an internal space ~~705a~~ 705a of the needle bearing ~~5~~ 705. This addition enables a bending torque can be further decreased. The

specific extreme-pressure additives may be exemplified as follows:

- Disulfide molybdenum
- Sulfur-series (S) extreme-pressure additives
- Sulfur-phosphorus-series (S-P) extreme-pressure additives
- Zinc-sulfur-phosphorus-series (Zn-S-P) extreme-pressure additives.

It is to be noted that this grease may be used in other embodiments.

As discussed above, according to the first through eighth embodiments of the present invention, the contact portion of the spider shaft sets its outside diameter larger than the outside diameter of the central portion thereof, and hence the fitting between this contact portion and the rolling bearing can be set to have the interference (or the minute gap). Accordingly, even when the vibrations are propagated, the noises emitted due to the interference therebetween can be ~~surely~~ reliably prevented by keeping uniform the minute gap between the central portion of the spider shaft and the rolling bearing.

On the other hand, the contact portion of the spider shaft has the bottomed hole formed in the axial core side end surface thereof and therefore takes ~~the~~ on a comparatively thin ring shape. Accordingly, the contact portion is relatively small in its

rigidity in the radial direction thereof and, even when the fitting between the contact portion and the rolling bearing is set to have the interference (or the minute gap), causes neither ~~the~~ a large contact surface pressure nor ~~the~~ a problem in terms of durability. Further, similarly, when assembling the cross joint to the yoke, the load for inserting (press-fitting) the rolling bearing (the needle bearing) is relatively small, and there is ~~caused~~ no ~~trouble to~~ real difficulty with the assembly process.

Moreover, there is no necessity of enhancing or improving the dimensional accuracy of each component, ~~and~~ the contact portion of the spider shaft is expanded in its diameter and is formed merely with the bottomed hole. This configuration does not bring about ~~the~~ a rise in the manufacturing cost.

Moreover, the contact portion of the spider shaft is, as described above, formed in ~~the~~ a comparatively thin ring shape. Therefore, if ~~the~~ a large load is propagated, the contact portion becomes flexural, however, the central portion of the spider shaft receives the large proportion of the load. Hence, there does not arise the problem in terms of ~~the~~ strength.

[Ninth Embodiment]

FIG. 10A is a side view including a partially cut-off section, showing a cross joint in a ninth

embodiment of the present invention. FIG. 10B is a sectional view of the cross joint illustrated in FIG. 10A.

As shown in FIG. 10A, the cross joint has the cross-shaped spider 3 is interposed between the pair of yokes 1 and 2. To be more specific, as shown in FIG. 10B, the spider shaft ~~6~~ 806 is fitted ~~in a possible of oscillating manner~~ into the bearing hole 4 of the yoke 1 through the needle bearing ~~5~~ 805 in a manner such that it is capable of oscillating movement. The seal member 7 is provided along the outer periphery of the lower portion of the spider shaft ~~6~~ 806. The yoke may be manufactured by any one of sheet metal working, forging and casting and composed of any one of ferro-series and alumi-series materials in the ninth embodiment and other embodiments which follow.

The pin 9 composed of the synthetic resin is inserted into the axial hole 8 formed in the axial core of the spider shaft ~~6~~ 806. The needle bearing ~~5~~ 805 is provided with the metallic bearing cup ~~10~~ 810 fitted in the bearing hole 4. The plurality of rolling members (rollers) ~~11~~ 811 are arranged inwardly of this cup ~~10~~ 810.

In the case of taking the conventional gap-fitting between the spider shaft ~~6~~ 806 and the needle bearing ~~5~~ 806 ~~the~~ noises ~~occure~~ occur during the traveling of the vehicle.

The ninth embodiment takes the interference-fitting between the needle bearing ~~5~~ 805 and the spider

shaft ~~6~~ 806, and hence the emission of the noises due to the interference between the spider shaft ~~6~~ 806 and the needle bearing ~~5~~ 805 can be surely prevented without bringing about the rise in the manufacturing cost. The interference is set to 0 through 0.035 mm and preferably 0.002 to 0.025 mm.

The needle bearing ~~5~~ 805 is classified as an overall roller type, an outside diameter of the cup ~~10~~ 810 is approximately 15 to 16 mm, an inscribed circle diameter of the roller ~~11~~ 811 is on the order of 10 mm, an outside diameter of the roller ~~11~~ 811 is 1.4 through 2.3 mm, and the number of rollers ~~11~~ 811 is 16 to 25.

When a steering shaft of the vehicle is steered, a steering wheel (unillustrated) is rotated, with the result that the spider shaft ~~6~~ 806 is oscillated. An angle of this oscillation is determined by a joint fitting angle in the vehicle and is on the order of ± 30 degrees in the case of an ordinary car.

The roller ~~11~~ 811 smoothly rotates owing to the oscillations of the spider shaft ~~6~~ 806, however, the axial core of the roller ~~11~~ 811 is not parallel but inclined to the axis of the spider shaft ~~6~~ 806 in many cases, and the roller ~~11~~ 811, with its rotation, moves in the axial direction within the cup ~~10~~ 810.

The inclination of the roller ~~11~~ 811 occurs in the case of the interference fitting as a result of ~~the test~~ testing and is substantially fixed depending on a gap in

the peripheral direction between the rollers ~~11~~ 811. In the ninth embodiment, this gap in the peripheral gap is 0.05 through 0.21 mm.

In the case of ~~the convention~~ a conventional steering joint, when the oscillations are caused, the rollers ~~11~~ 811 would ordinarily move in the axial direction and come into contact with ~~on~~ either walls ~~10a, 10b~~ 810a, 810b of the cup ~~10~~ 810, and sliding ~~occurs~~ would occur between the rollers ~~11~~ 811 and the walls ~~10a, 10b~~ 810a, 810b of the cup ~~10~~ 810. Further, ~~the~~ sliding in the axial direction ~~occurs~~ would occur between the rollers ~~11~~ 811 and the spider shaft ~~6~~, 806 whereby the bending torque would increase (~~there increases a~~ resistance increases when oscillated). Especially when the fitting gap is ~~minus~~ negative (interference), this tendency becomes conspicuous.

According to the ninth embodiment, a gap (M-N) in the roller axial direction within the cup ~~10~~ 810 is set to 0.6 mm or larger. This gap (M-N) is determined from result of a multiplicity of tests and is preferably 0.9 mm or greater. Namely, the roller within the bearing cup of the needle bearing is so structured as to be movable 0.6 mm or larger in the axial direction. As a result, when the joint is bent, the rollers ~~11~~ 811 rotate and move in the axial direction within the cup ~~10~~ 810 with the oscillations of the spider shaft ~~6~~ 806. Even in such a case, the walls ~~10a, 10b~~ 810a, 810b of the cup ~~10~~ 810 have neither the contact~~s~~ of the rollers ~~11~~ 811 nor ~~the~~ sliding with respect to the rollers.

Accordingly, a smooth feeling of the steering can be obtained by reducing the bending torque of the steering shaft.

~~Note that~~ there might be a case where the rollers ~~11~~ 811 have already been brought into contact with the walls ~~10a, 10b~~ 810a, 810b of the cup ~~10~~ 810 after the assembly, or a case where the rollers ~~exist~~ reside in the vicinity of the walls ~~10a, 10b~~ 810a, 810b. In this case, with the joint bent, the rollers ~~11~~ 811 are once brought into contact with the walls ~~10a, 10b~~ 810a, 810b, and the bending torque increases. When the joint gets resilient from the bending state, however, the rollers ~~11~~ 811 become separate from the walls ~~10a, 10b~~ 810a, 810b and move in the opposite direction (i.e., in the central direction) owing to inclinations of the rollers ~~11~~ 811. Next, even when bent in the same direction as done for the first time, a bending angle thereof is kept till the rollers ~~11~~ 811 come into contact with the walls ~~10a, 10b~~ 810a, 810b of the cup ~~10~~ 810, and therefore the bending torque does not increase.

[Tenth Embodiment]

FIG. 11 is a sectional view showing a cross joint in a tenth embodiment of the present invention. The tenth embodiment does not involve the use of the synthetic resin pin ~~9~~. Other configurations and operations are the same as those in the ninth embodiment.

[Eleventh Embodiment]

FIG. 12 is a sectional view showing a cross joint in an eleventh embodiment of the present invention. According to the eleventh embodiment, a bottom wall of the cup ~~10~~ 910, 910a, 910b is formed with a protrusion ~~10c~~ 910c coming into contact with the side end surface of the spider shaft ~~6~~ 906. Further, the side end surface of the roller ~~11~~ 911 in the bearing is spherical. Other configurations and operations are the same as those in the ninth embodiment.

[Twelfth Embodiment]

FIG. 13A and 13B are sectional views each showing a cross joint in a twelfth embodiment of the present invention. According to the twelfth embodiment, the spider shaft ~~6~~ 1006 has a stepped portion, and a length of the contact with the roller 11 is set short. Namely, an end-side major diameter of the spider shaft ~~6~~ 1006 is set small in FIG. 13A, and a proximal-side major diameter of the spider shaft ~~6~~ 1106 is set small in FIG. 13B. With these settings, when the bearing is assembled, a press-fitting load thereof becomes small because of the short contact length with the spider shaft ~~6~~, thereby facilitating the assembly. Other configurations and operations are the same as those in the ninth embodiment.

[Thirteenth Embodiment]

FIG. 14A is a sectional view showing a cross

joint in a thirteenth embodiment of the present invention. In the thirteenth embodiment, a piece ~~12~~ 20 composed of the synthetic resin is used as a substitute for the synthetic resin pin 9. That is, the piece ~~12~~ 20 is provided between the bottom surface of the cup ~~10~~ 110 and the side end surface of the spider shaft ~~6~~ 106. Other configurations and operations are the same as those in the ninth embodiment.

Further, the extreme-pressure additive is added to the grease (lubricating oil) filling the internal space ~~5a~~ 105a of the needle bearing ~~5~~ 105. This addition enables the bending torque can be further decreased. The specific extreme-pressure additives may be exemplified as follows:

- Disulfide molybdenum
- Sulfur-series (S) extreme-pressure additives
- Sulfur-phosphorus-series (S-P) extreme-pressure additives
- Zinc-sulfur-phosphorus-series (Zn-S-P) extreme-pressure additives.

It is to be noted that this grease may be used in other embodiments. Moreover, the length (L) of the interference-fitted portion is set equal to or larger than 1.5 mm, preferably 2 mm on the basis of calculations and results of a multiplicity of tests performed. With this dimensional requirement attained, the durability can be ensured.

[Fourteenth Embodiment]

FIG. 14B is a sectional view showing a cross joint in a fourteenth embodiment of the present invention. In accordance with the fourteenth embodiment, the needle bearing ~~5~~ 1205 is provided with a cage 13. In this case, the following relationship is established.

$$M - N - S1 - S2 \geqq 0.6 \text{ mm}$$

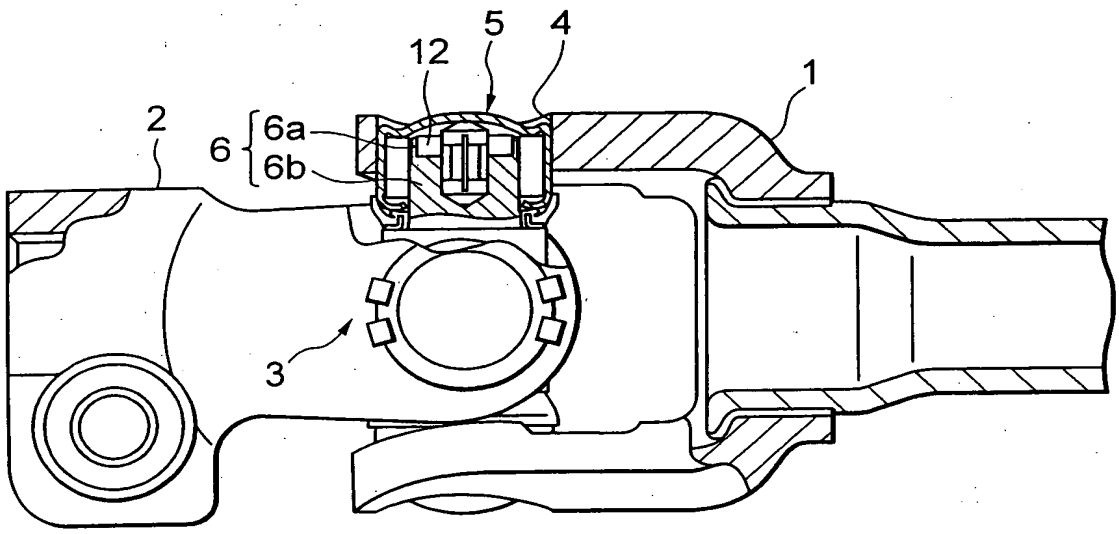
According to the fourteenth embodiment, the needle bearing ~~5~~ 1205 is provided with the cage 13, and consequently the cost is higher than in other embodiments that do not involve the use of the cage. The rollers ~~11~~ 1211 are, however, inclined without no relation with each other and therefore have a less possibility of their being tilted in one direction as in the overall roller type. Hence, a force by which the spider shaft ~~6~~ 1206 moves in the axial direction is small, and an anti-abrasion of the contact portion between the protrusion ~~10c~~ 1210c on the bottom wall of the cup ~~10~~ 1210 and the side end surface of the spider shaft ~~6~~ 1206 is enhanced.

The ninth through fourteenth embodiments involve the use of the shell type needle bearing and may also involve the use of a solid type needle bearing. Further, two shafts facing to each other may take the shell type needle bearing, and the two shafts substantially orthogonal ~~thereto~~ thereto may take the

solid type needle bearing.

SEP 0 2 2003
PATENT & TRADEMARK OFFICE

FIG. 1



SEP 0 2 2003
PATENT & TRADEMARK OFFICE

REPLACEMENT SHEET

FIG. 2

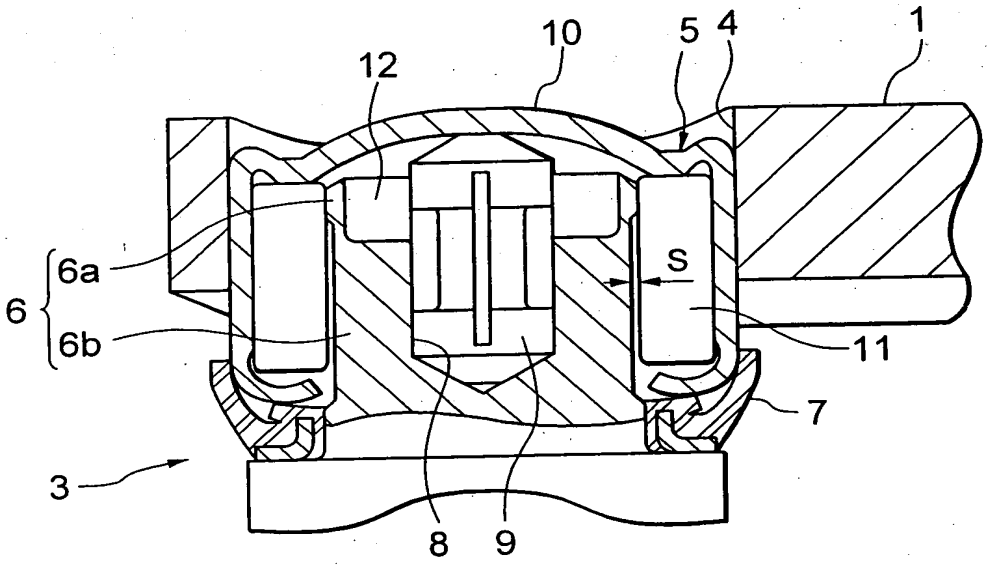
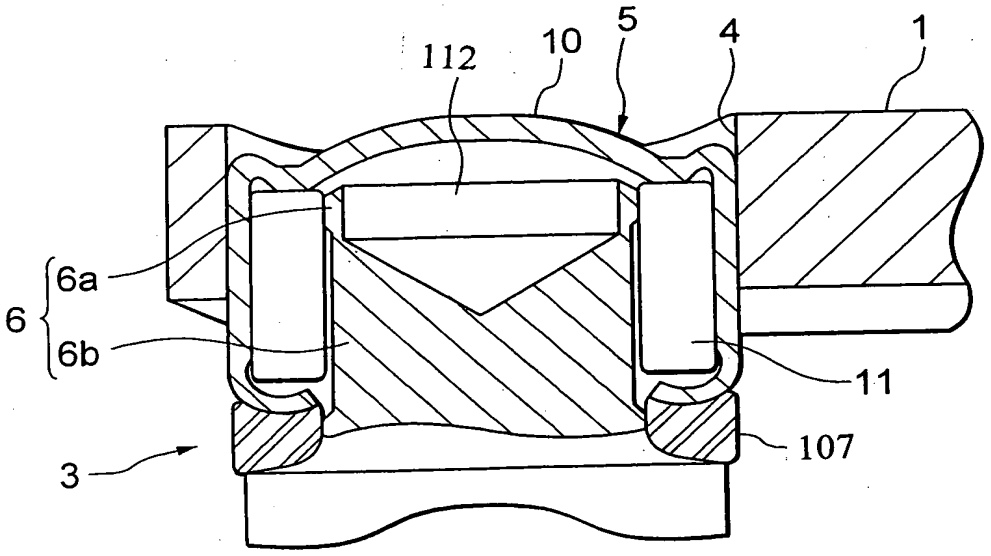


FIG. 3



SEP 0 2 2003
PATENT & TRADEMARK OFFICE

FIG. 4

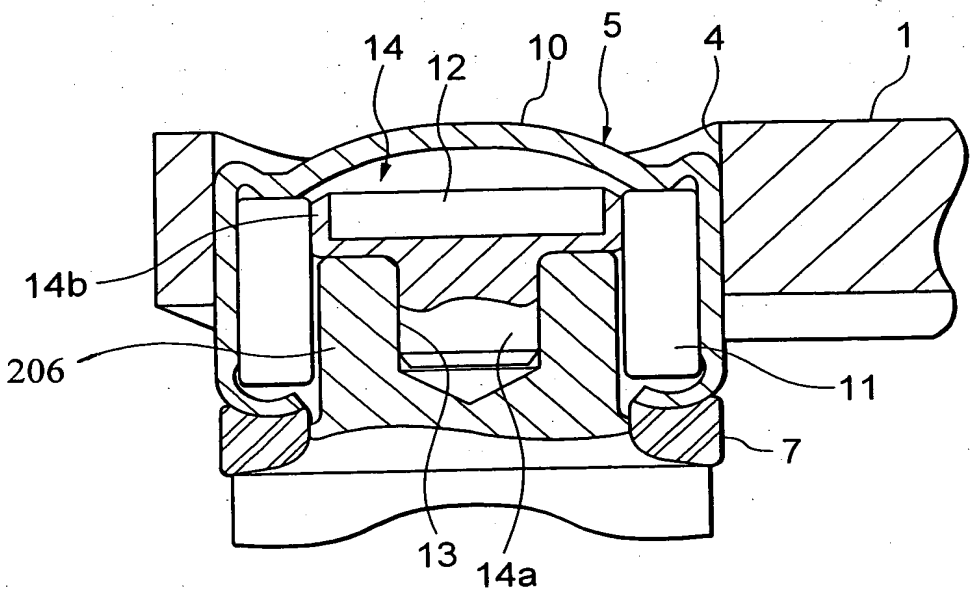
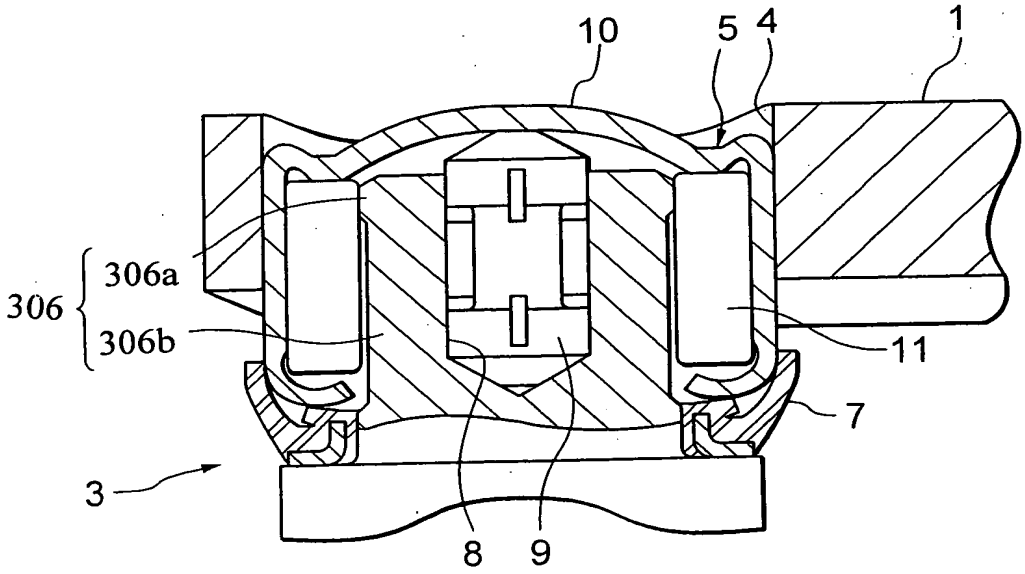


FIG. 5



OIPE
SEP 0 2 2003
PATENT & TRADEMARK OFFICE

FIG. 6

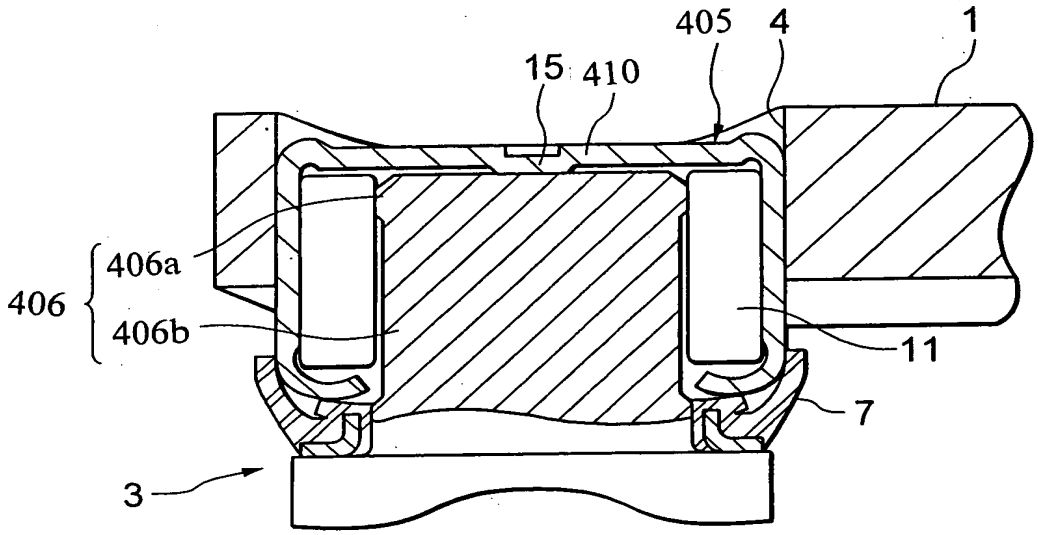
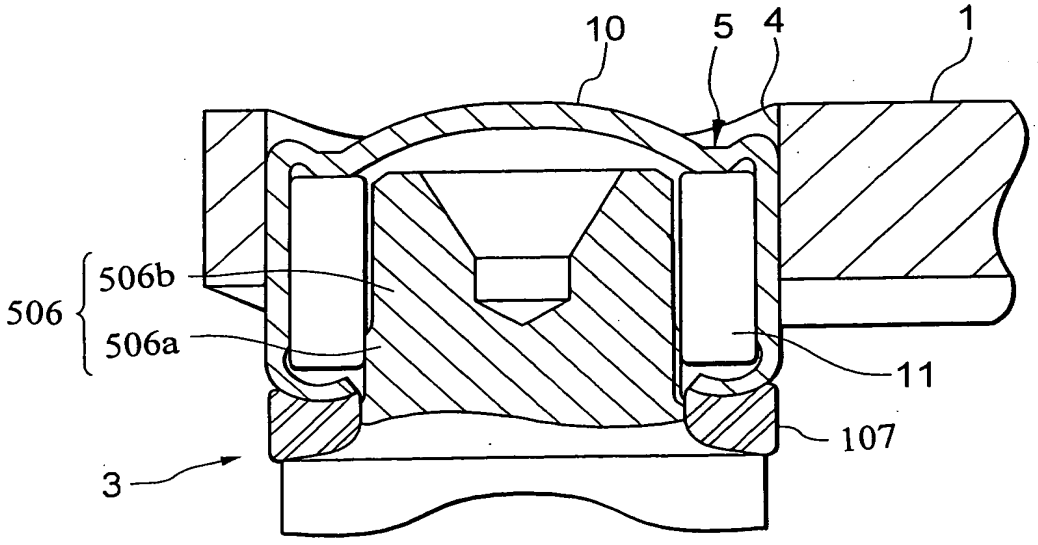


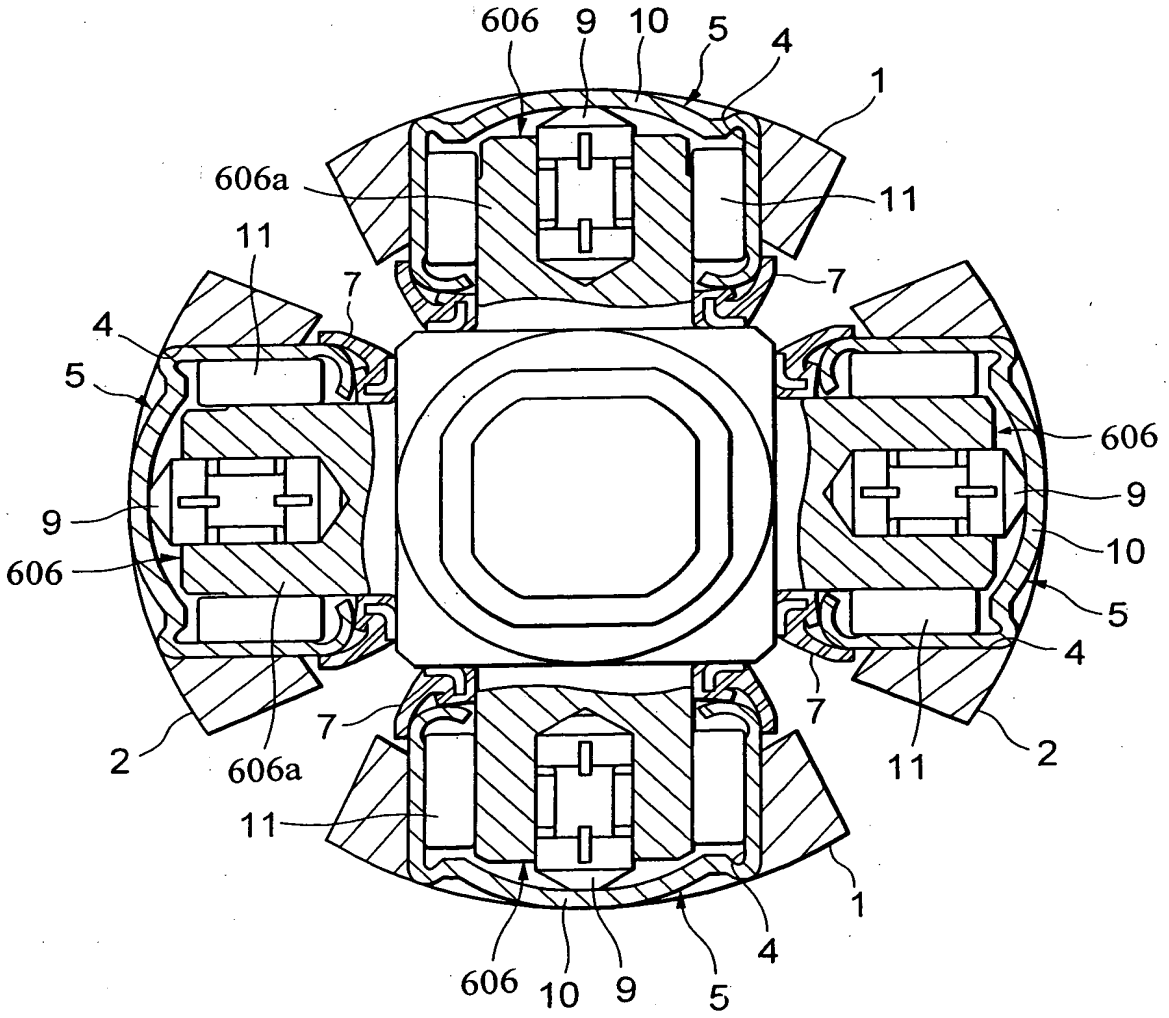
FIG. 7



SEP 0 2 2003
PATENT & TRADEMARK OFFICE

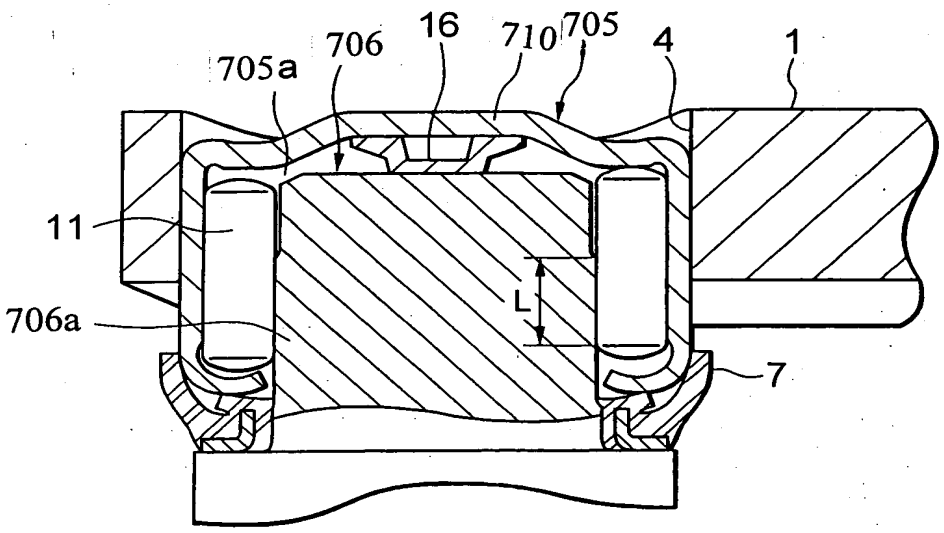
REPLACEMENT SHEET

FIG. 8



SEP 0 2 2003

FIG. 9



SEP 0 2 2003

FIG. 10A

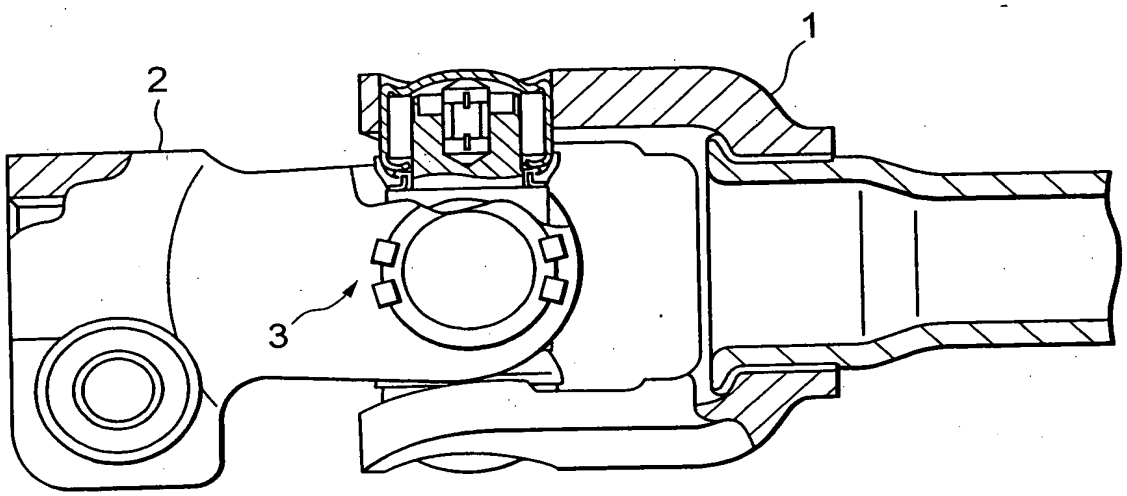
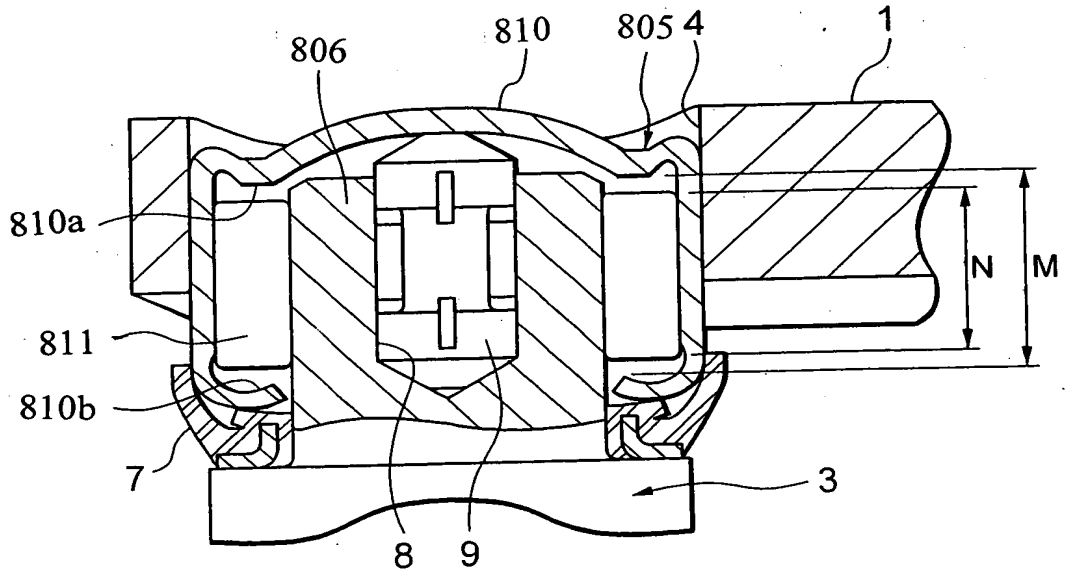


FIG. 10B



O I P E
SEP 0 2 2003
PATENT & TRADEMARK OFFICE

FIG. 11

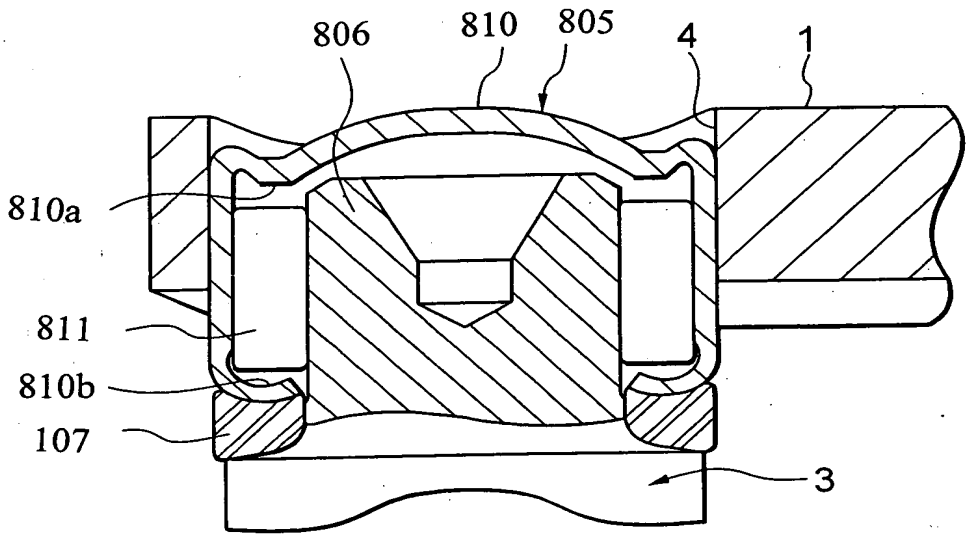
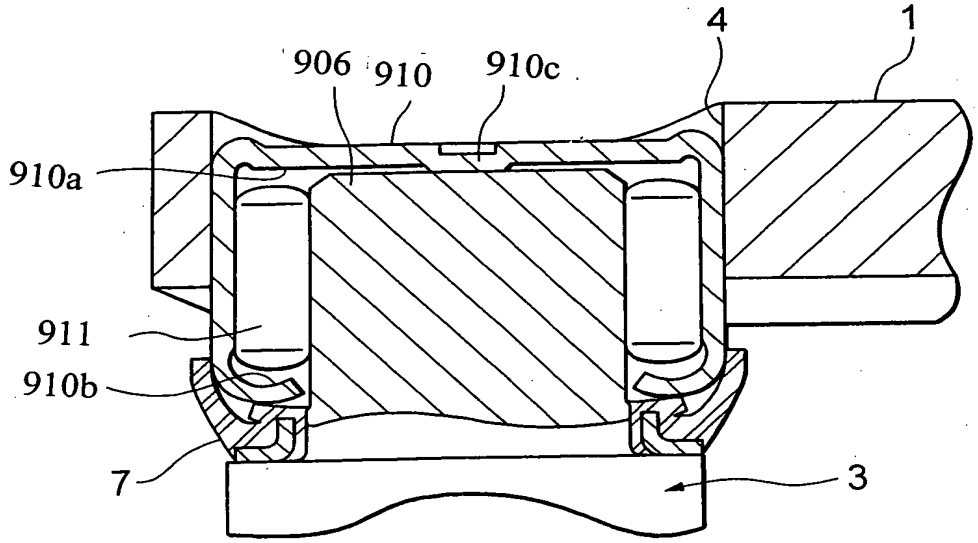


FIG. 12



SEP 0 2 2003

FIG. 13A

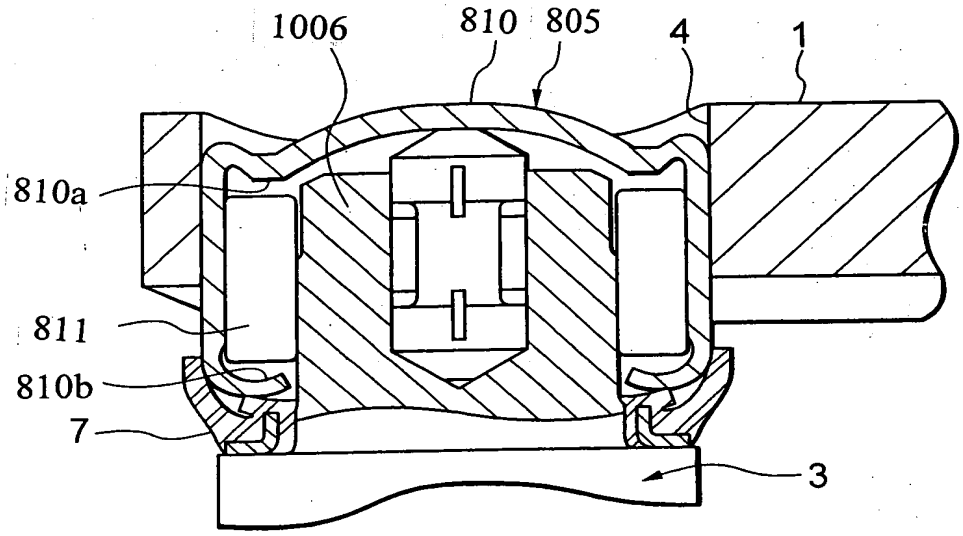
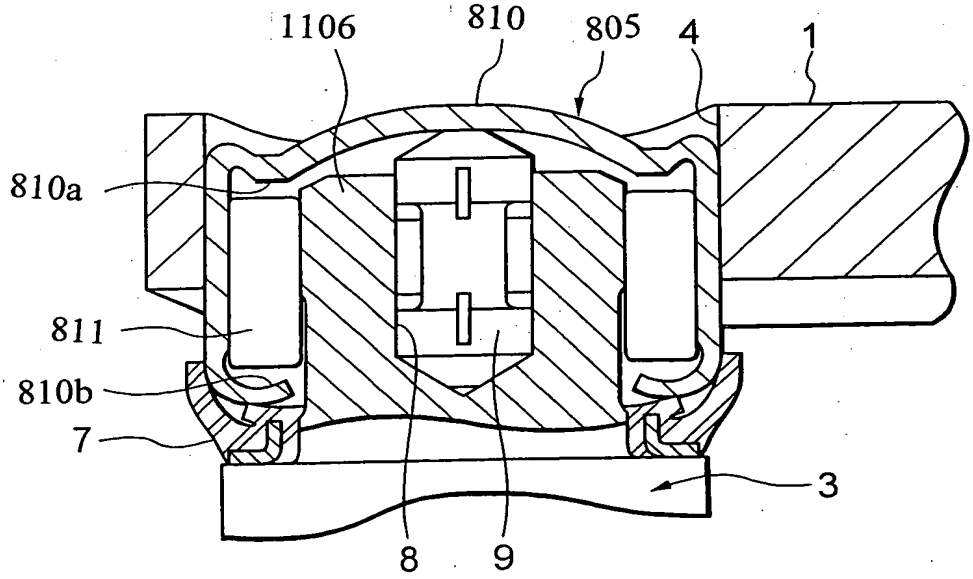


FIG. 13B



O.I.P.E.
SEP 0 2 2003
PATENT & TRADEMARK OFFICE U.S.

FIG. 14A

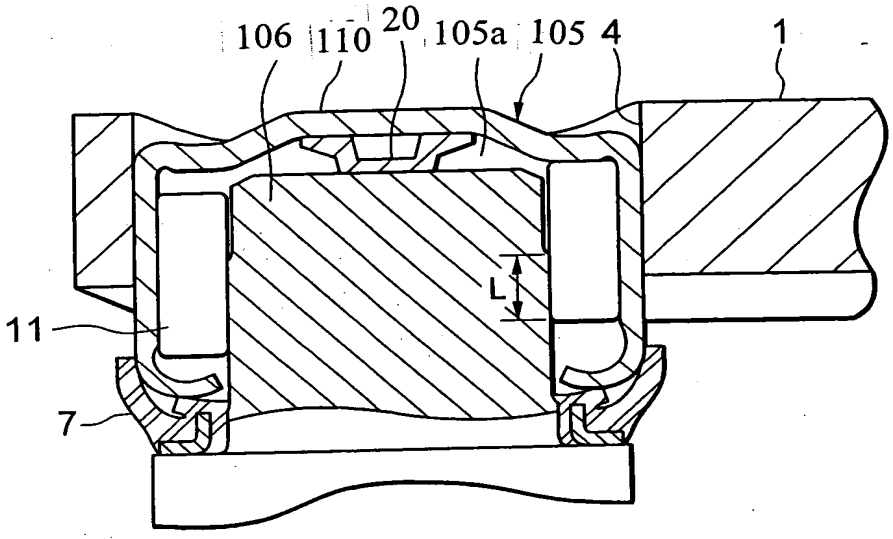


FIG. 14B